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power of the concentrations, hence are important even in very dilute solutions.

[1] Duhem, *Méchanique Chimique*, Livre VI, Chap. 111. The function $T\partial\varphi/\partial T - \varphi$ is identically equal to Gibbs' heat function $U + pv$.

[2] *Ibid.*

[3] Van Laar, *Sechs Vortrage u. d. thermodynamische Potential*, S. 84.

[4] *Technology Quart., Boston*, **21**, 1908 (372).

[5] *Ibid.*, p. 371.

[6] Adams, L. H., *J. Amer. Chem. Soc.*, **37**, 1915 (481).

[7] MacInnes and Braham, *Ibid.*, **39**, 1917 (2110).

[8] *Amer. Chem. Jour.*, **34**, 1905; **37, 38**, 1907.

[9] *Zs. phys. Chem.*, **31**, 1899; and **27**, 1898.

[10] Duhem, *loc. cit.*

[11] These PROCEEDINGS, **3**, 1917 (569); see also *J. Amer. Chem. Soc.*, **40**, 1918 (106–158).

[12] These PROCEEDINGS, **3**, 1917 (574) and *J. Amer. Chem. Soc.*, **40**, 1918 (145).

THE FORMATION OF THE CELL PLATE IN THE CAMBIUM OF THE HIGHER PLANTS

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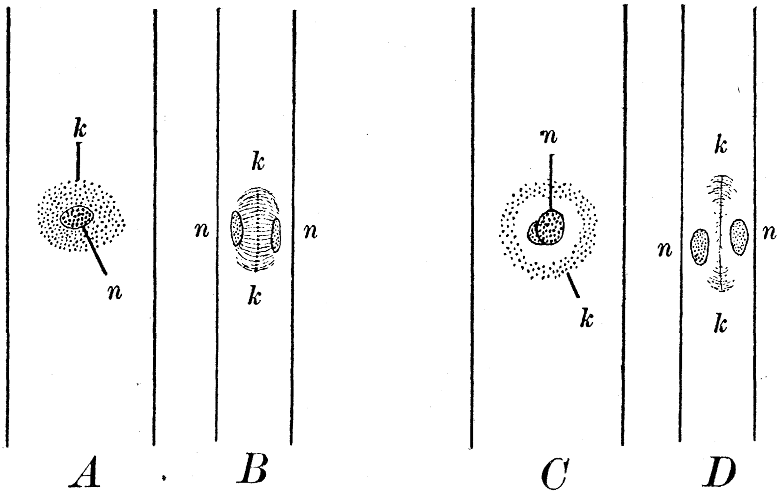
Communicated by W. M. Wheeler, February 17, 1920

In a previous note[1] the writer called attention to a remarkable type of cytokinesis that occurs in the cambium of Coniferae. The process of cell plate formation is greatly extended, both as regards space and time and is clearly dissociated, except in its initial stages, from the usual phenomena of karyokinesis. Since this type of cell division promises to be of considerable significance in the study of various cytological and physiological problems[2] it is desirable to determine whether it is an isolated phenomenon, i.e., confined to the Coniferae, or one that is characteristic of the cambia of all of the higher plants, angiosperms as well as gymnosperms.

During the last growing season, I secured specimens of the cambium from an extensive series of angiosperms. Selections were made so as to include representatives of all of the larger and more important orders of the dicotyledons and of certain arborescent monocotyledons which have "secondary" growth in thickness. Specimens were obtained from both tropical and temperate environments.

Although the cambial initials in mature stems of angiosperms are on an average considerably smaller than homologous elements of gymnosperms[3] the salient features of cytokinesis are the same in both subphyla. In the former, as in the latter group, each initial contains a single nucleus which is centrally located and divides mitotically. The spindle becomes extended laterally by the addition of peripheral "fibers"[4] and gradually assumes the form of a disk, figures *A* and *B*. As more fibers are successively added the original "connecting fibers" disappear from about the cell plate, leaving a ring-shaped aggregation of kinoplasmic fibers, which in tangential longitudinal sections of the cambium appears as a halo about the daughter nuclei, figure *C*. This ring increases in circumference until it intersects the radial walls, when it becomes more or less flattened on two sides. As soon as the cell plate intersects the radial walls of the cell, the fibers in these two sides disappear leaving two separate aggregations of kinoplasmic fibers which are connected by the cell plate, figures *E*, *F*, *G*, *H*. These aggregations of fibers, kinoplasmasomes, have the same characteristic shape and structure as those which occur in the Coniferae. They extend across the cell—more or less at right angles to its longitudinal axis—from one radial wall to the other, figure *G*, and are located in the center of the protoplast, midway between its tangential surfaces, figure *H*. They move in opposite directions—*usually at equal rates*—towards the ends of the cell. As they move forward, the cell plate is extended until it eventually reaches the two ends of the protoplast, thus dividing it into halves, each of which contains one of the daughter nuclei. The latter usually remain close together near the center of the cell during cytokinesis, as in the gymnosperms; and I have been unable to find any visible connection between them and the kinoplasmasomes.

Robinia Pseudo-Acacia L.



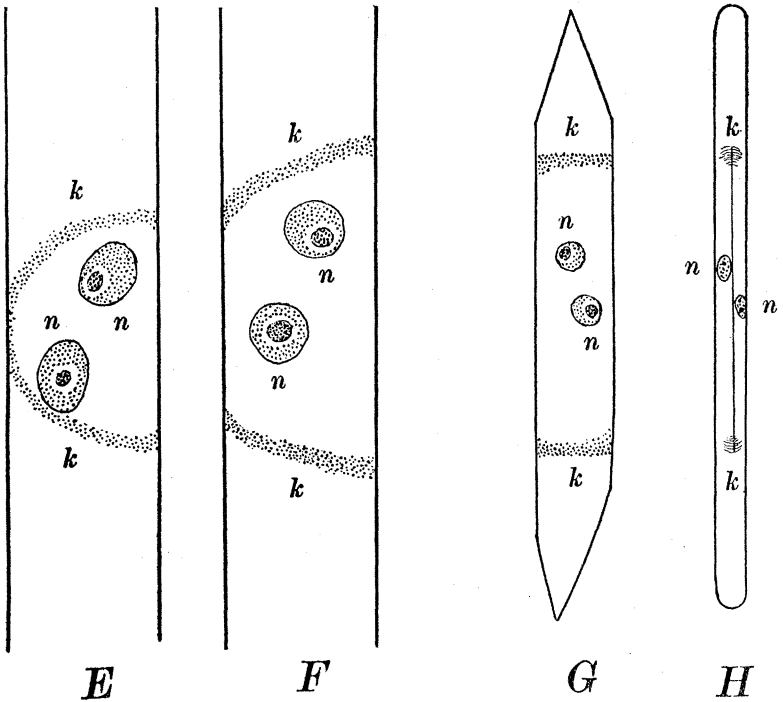
A. Central portion of cambial initial, in tangential longitudinal extension, showing early "disk" stage in the formation of the cell plate. X 900.

B. The same. Radial longitudinal extension. X 900.

C. Central portion of cambial initial, in tangential longitudinal extension, showing "ring" or "halo" stage in the formation of the cell plate. X 900.

D. The same. Radial longitudinal extension. X 900.

Having determined that this type of cytokinesis is characteristic of the cambia of both gymnosperms and angiosperms, it is of interest to inquire whether it ever occurs in other somatic tissues, and what relation it bears to those types of cell plate formation which previously have been described by Treub,[5] Strasburger[6] and Schürhoff.[7] The writer has accumulated considerable evidence which indicates that the phenomenon in question is not confined to the cambium, but occurs in other somatic tissues, in elongated or much flattened cells whose planes of division have one long and one short dimension. Furthermore, a comparative study of cytokinesis in different somatic tissues and in cells of different shapes and sizes suggests that the various types of cell plate formation, described by Treub, Strasburger, Schürhoff and the writer, are but different phases or stages of a single general or fundamental type of cytokinesis. The particular expressions of the phenomenon which may occur in any given



Robinia Pseudo-Acacia L.

E. Central portion of cambial initial, in tangential longitudinal extension, showing disappearance of two arcs of the kinoplasmic ring. X 900.
F. Central portion of cambial initial, in tangential longitudinal extension, showing early kinoplasmasome stage in the formation of the cell plate. X 900.
G. Cambial initial, in tangential longitudinal extension, showing later kinoplasmasome stage in the formation or the cell plate. X 450.
H. The same. Radial longitudinal extension. X 450.
n. Daughter nucleus.
k. Kinoplasma.

cell are dependent upon the dimensions of the latter, its plane of division and the size and location of the nucleus. Thus, in very small, isodiametric cells, having a large centrally located nucleus, the cell plate quickly intersects the walls of the cell, without any extensive laterial growth—by means of additional peripheral fibers—of the spindle. In somewhat larger elements there is sufficient room for the process of cytokinesis to reach the "halo" stage before the cell plate intersects the sides of the cell. Only in elongated or much flattened elements, i.e., cells which are not isodiametric, is it possible for the phenomenon of cell plate formation to pass through the "spindle," "disk," "halo" and "frame" stages and finally form two entirely separate aggregations of kinoplasmic fibrillae, the kinoplasmasomes.

It is evident, accordingly, that the remarkable type of cell plate formation which was described in a former note, is not an isolated or unusual phenomenon, but is of frequent occurrence in the somatic tissue of the higher plants, gymnosperms and angiosperms. It promises to be significant in any general discussion concerning the dynamics of cytokinesis and karyokinesis.

[1] Phenomena of cell division in the cambium of arborescent gymnosperms and their cytological significance, these PROCEEDINGS, **5,** 1919 (283–285).

[2] Bailey, I. W., The significance of the cambium in the study of certain physiological problems, *J. Gen. Physiol.* Ined.

[3] The average length of the cambial initials in 152 stems of gymnosperms was computed as approximately 3400 micra; in 275 stems of dicotyledons as approximately 600 micra.

[4] The word fibers is used without reference to whether the fibrillae are true threads or lines of protoplasmic streaming in the living cell.

[5] Treub, M., "Quelques recherches sur le rôle du noyau dans la division des cellules végétales," *Verh. K. Akad. Wetensch. Amsterdam,* **19,** 1879 (1–35).

[6] Strasburger, E., *Zellbildung und Zelltheilung,* 3 aufl, Jena, 1880.

[7] Schürhoff, P., "Das Verhalten des Kernes im Wundgewebe," *Beih. Bot. Central.,* **19,** 1906 (359–382).

FUNCTIONALS INVARIANT UNDER ONE-PARAMETER CONTINUOUS GROUPS OF TRANSFORMATIONS IN THE SPACE OF CONTINUOUS FUNCTIONS

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Communicated by G. A. Bliss, February 20, 1920

1. *Some general notions.*—It is intended in this abstract to give a few examples of one-parameter continuous groups of transformations in function space which are analogues of well-known groups in the space of a finite number of dimensions, and to exhibit in each case a functional invariant in terms of which every invariant of the group (with suitable restrictions) is expressible. Some of these groups have already been con-